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54 Method for preparing organohalosilanes.

57 The present invention provides a method for reducing the concentration of methyltrichlorosilane in the mixture of methylchlorosilanes obtained from the direct process reaction of silicon metal with a mixture of methyl chloride and hydrogen chloride. The method comprises blending the methyl chloride/hydrogen chloride mixture with from 0.1 up to about 5 weight percent of hydrogen, based on the methyl chloride.

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METHOD FOR PREPARING ORGANOHALOSILANES

This invention relates to the preparation of organohalosilanes. More particularly, this invention relates to a method for increasing the yield of monoorganodichlorosilanes and/or reducing the yield of undesired monoorganotrichlorosilanes using a method referred to in the art as the "direct process" without either adversely affecting the yield of other desirable organochlorosilanes, particularly the combined yield of monoorganodichlorosilane and the corresponding diorganodichlorosilane or generating substantial quantities of undesirable inorganic halosilanes and organotrihalosilanes.

The preparation of organohalosilanes by the reaction of an alkyl or aryl halide with silicon metal in the presence of various catalysts is known as the "direct process". The halide portion is typically chlorine, but can also be bromine or iodine.

Preparing halosilanes by reacting silicon with hydrogen chloride has been known since the work of Buff and Wohler in 1857 and Combes in 1896. Application of the direct process to the preparation of organohalosilanes was first disclosed by Rochow and his co-workers, beginning in the mid-1940's. The art describes numerous improvements to this direct process.

For various reasons, including cost and availability of starting materials, alkylchlorosilanes, particularly methyl- and ethylchlorosilanes, have become the organohalosilanes most frequently prepared by the direct process. The present invention has therefore been limited to this class of alkylchlorosilanes using the corresponding alkyl chlorides. It should be understood that while preferred embodiments of the present invention are directed primarily to the preparation of certain methylchlorosilanes by reacting methyl chloride and silicon, the invention is not to be so limited.

When methyl chloride, represented by the formula MeCl , and silicon metal are reacted using the catalysts and reaction conditions described in the prior art, the resultant products include but are not limited to MeHSiCl_2 , Me_2SiCl_2 , Me_3SiCl , MeSiCl_3 , Me_2HSiCl , HSiCl_3 and SiCl_4 , where Me represents the methyl radical. By an appropriate selection of catalyst and reaction conditions it is possible to obtain dimethyldichlorosilane, Me_2SiCl_2 , as the major component, often 90 weight % or more, in the final product mixture. Methyldichlorosilane, MeHSiCl_2 typically constitutes about 1 weight percent of the product under these conditions, which are designed to optimize the yield of Me_2SiCl_2 . The reaction product also typically contains a significant concentration of methyltrichlorosilane, MeSiCl_3 , which in many instances is not a desired product.

The prior art provides no teaching to enable one to increase the relative concentration of methyldichlorosilane in a direct process product mixture without either a substantial decrease in the combined yield of this product and dimethyldichlorosilane or producing substantial amounts of undesirable products, particularly methyltrichlorosilane and carbon. Carbon is especially undesirable because it collects on the silicon reaction mass and may decrease the rate of the methyl chloride/silicon reaction or cause it to stop all together.

The art teaches combining the methyl chloride with 5 weight percent or more, based on methyl chloride, of hydrogen as a means for increasing the relative yield of methyldichlorosilane in the final product, however, the yield of dimethyldichlorosilane is more than correspondingly reduced and substantial quantities of undesirable organic halosilanes are produced.

The prior art also teaches combining the methyl chloride with 5 weight percent or more, based on methyl chloride, of hydrogen chloride as a means for increasing the relative yield of methyldichlorosilane in the final product, however the yield of dimethyldichlorosilane is more than correspondingly reduced and substantial quantities of undesirable inorganic halosilanes are produced.

Methods for increasing the yields of dimethyldichlorosilane while reducing the yield of methyltrichlorosilane obtained using the direct process are described in the prior art:

An objective of this invention is to provide a method for increasing the yield of methyldichlorosilane in the direct process without substantially affecting the combined yield of this silane, dimethylchlorosilane and dimethyldichlorosilane or producing excessive amounts of methyltrichlorosilane or inorganic chlorosilanes such as SiCl_4 and SiHCl_3 .

The present invention is based on the discovery that when small concentrations of hydrogen and hydrogen chloride are blended with the methyl chloride that is reacted with silicon metal to form methylchlorosilanes, the yield of methyldichlorosilane is increased without producing substantial amounts of undesirable methyltrichlorosilane, SiCl_4 and/or SiHCl_3 or adversely affecting the combined yield of methyldichlorosilane, dimethylchlorosilane and dimethyldichlorosilane.

This invention provides an improvement in the method for increasing the yield of methyldichlorosilane obtained during the production of methylchlorosilanes by the reaction of a gaseous mixture comprising

methyl chloride and hydrogen chloride with a reaction mass comprising silicon metal and a suitable catalyst at a temperature of from 250 to about 350° C. The improvement comprises homogeneously blending the methyl chloride and hydrogen chloride with an amount of hydrogen sufficient to reduce the concentration of methyltrichlorosilane in the product of said reaction.

5 U.S. application Serial No. 459,630 filed January 2, 1990, teaches using small amounts of hydrogen chloride in the direct process for preparing alkylchlorosilanes. When less than about 1 weight percent of hydrogen chloride is combined with methyl chloride the concentration of methyldichlorosilane in the reaction product is substantially increased without substantially decreasing the combined yield of this silane and dimethyldichlorosilane. At higher concentrations of hydrogen chloride this process yields relatively large
10 concentrations of methyltrichlorosilane, SiCl_4 and SiHCl_3 , all of which are usually undesirable by-products.

The present inventors discovered that by using a mixture of hydrogen, hydrogen chloride and methyl chloride in the direct process, the beneficial effects of both modifiers can be obtained with a reduction in the disadvantages of each.

15 In accordance with the present method from 0.02 to 10 weight percent of a mixture of hydrogen chloride and hydrogen, based on methyl chloride, is introduced together with the methyl chloride. Experimental data generated by the present inventors indicate that the hydrogen chloride to hydrogen ratio is not critical, so long as the hydrogen concentration does not exceed 5 percent, based on methyl chloride weight. The hydrogen typically constitutes from 5 to about 90 weight percent of the hydrogen/hydrogen
20 chloride mixture.

The limits for the combined hydrogen/hydrogen chloride concentration are preferably from 0.1 to about 3 percent of the methyl chloride weight and hydrogen constitutes from 10 to about 60 weight percent of this mixture.

When the present method is conducted in a batch or semi-batch mode the present inventors found it desirable to have more of the hydrogen chloride present during the initial methyl chloride addition and
25 reduce or eliminate hydrogen chloride during the terminal portion of the methyl chloride addition. In accordance with a particularly preferred embodiment, hydrogen chloride is present in only the initial 50 to about 90 weight % of the methyl chloride added to the reactor.

The optimum concentration ranges for the hydrogen chloride and hydrogen and the relative concentrations of these gases with respect to one another are at least partially dependent on the type of equipment
30 and reaction conditions used in practicing the present method. Suitable equipment for conducting the direct process include fixed bed, stirred bed and fluid bed reactors. Any of these reactors can be operated in a continuous or batch mode.

It is within the scope of the present invention to utilize the reactor described in United States Patent No. 3,133,109, which issued to Dotson on May 12, 1964 or the one described by Maas et al. in United States
35 Patent No. 4,218,387.

The particle size of the fluidized material should be within the range typically used for the direct process. Dotson in United States Patent No. 3,133,109 discloses particle size range of from 20 to 200 microns. Depending upon the capacity of the reactor, a range of from 1 to 200 microns is preferred for the present method.

40 The temperature range used for the direct process is typically from 250 to about 350° C. Temperatures within the range of from 260 to about 330° C. are preferred to optimize yields of the desired methylchlorosilanes.

The combination of high yields of dimethyldichlorosilane and dimethylchlorosilane together with a reduction in the concentration of methyltrichlorosilane achieved using the present method is believed due to
45 1) the mixture of hydrogen chloride, hydrogen and methyl chloride that is reacted with silicon and 2) the presence of a catalyst composition that will suppress the formation of methyltrichlorosilane during this reaction.

Catalysts suitable for use in the present method include but are not limited to copper or a copper compound in combination with at least one of tin and zinc. The tin and zinc can be in the form of the metals
50 or compounds of these metals.

The art pertaining to the direct process for preparing alkylhalosilanes discloses a variety of catalysts and promoters suitable for use in the direct process.

United States Patent No. 4,500,724, which issued to Ward et al. discloses catalysts for the production of organohalosilanes comprising copper and copper oxides, tin or tin-containing compounds and zinc or zinc-
55 containing compounds. In accordance with the teaching of this patent, the concentration of methyltrichlorosilane in a silicon/methyl chloride reaction product is reduced using specified ratios of copper, zinc and tin as the catalyst for the reaction.

Halm et al. in U.S. Patent No. 4,602,101, issued July 22, 1986, discloses catalysts for controlling

product selectivity and increasing silicon conversion during the reaction of an alkyl halide with metallurgical grade silicon at a temperature of 250-350° C. The catalysts for this reaction are combinations of copper or a copper compound with tin or a tin compound. The reaction mass also contains phosphorous or phosphorous-containing compounds as reaction promoters. The concentration of phosphorus or phosphorus compound is from 25 to 2500 parts by weight per million parts (ppm) of initial reaction mass, the concentration of copper is from 0.2 to 10 weight percent, based on the initial weight of the reaction mass and the concentration of tin is from 5 to 200 ppm.

The concentration limits on phosphorus, copper and tin disclosed in the aforementioned patent to Halm et al. also apply to the reaction mixtures of the present invention. When zinc is used as a catalyst, it is preferably present at a concentration of present at a concentration of from 10 to 10,000 ppm, based on initial reaction mass. The silicon can also contain up to one weight percent each of aluminum and/or iron.

Additional suitable catalysts and promoters that can be used with copper in combination with tin and/or zinc contain at least one element selected from zinc, calcium, barium, titanium, zirconium, cadmium, lead, bismuth, arsenic, nickel, antimony, silver and cobalt. Any of these promoters can be used in its elemental form or as compounds or alloys that contain the element.

Preferred catalyst/promoter compositions include but are not limited to:

1. (a) Copper or a copper compound and (b) zinc or a zinc compound;
2. (a) Copper or a copper compound, (b) zinc or a zinc compound and (c) tin or a tin compound;
3. (a) Copper or a copper compound, (b) tin or a tin compound and (c) optionally arsenic or an arsenic compound;
4. (a) Copper in the form of a mixture, alloy or compound, (b) at least one member selected from the group consisting of tin, tin compounds, zinc and zinc compounds and (c) at least one member selected from the group consisting of phosphorus, phosphorus compounds, metal-phosphorus alloys and metal phosphides;
5. (a) Copper or a copper compound, (b) tin or a tin compound, (c) arsenic or an arsenic compound and (d) phosphorus or a phosphorus compound;
6. (a) An alloy of silicon with either iron alone or iron in combination with aluminum, where the concentrations of iron and aluminum are less than one weight percent, based on the weight of initial silicon, (b) copper or at least one copper compound and, optionally, at least one member selected from the group consisting of tin, tin compounds, zinc, zinc compounds, elemental phosphorus, metal phosphides and metal-phosphorus alloys; and
7. (a) A mixture of copper and zinc that is present as brass, (b) cuprous chloride, (c) tin or at least one tin compound and (d) a metal-phosphorus alloy.

The metal portion of any metal-phosphorus alloy or phosphide is preferably aluminum, calcium, copper or zinc.

Those promoters for which concentration ranges are not disclosed in the preceding specification are typically used in amounts as low as several parts per million. Up to 10 weight percent, based on initial reaction mass, of some of these promoters can be used without any adverse effects.

For best results, the purity of the silicon should be at least 95% but less than 100%. A metallurgical grade of silicon is preferred. For optimum results the silicon is in a particulate form.

The following examples describe preferred embodiments of the present invention with respect to types and concentrations of reactants, catalysts, promoters, process conditions and equipment and should not be interpreted as limiting the present invention as defined in the accompanying claims. Unless otherwise indicated, all parts and percentages in the example are by weight.

The following general procedure was used in the examples. The reactions between silicon and methyl chloride or methyl chloride/hydrogen chloride/ hydrogen mixtures was conducted in a fluidized bed reactor of the type described in U.S. Patent No. 3,133,109 to Dotson. The temperature of the sand bath used to heat the reactor was 315° C. and each heating period, equivalent to the reaction time, was 44 hours in duration.

Metallurgical grade silicon (Globe Metallurgical, Inc. Beverly, Ohio) was employed which contained aluminum (0.22%), calcium (0.046%) and iron (0.34%). The hydrogen and hydrogen chloride used were of 99.999% minimum purity, obtained from Matheson Gas Products, Dayton, Ohio. The methyl chloride and hydrogen were individually metered using calibrated flowmeters. When hydrogen was used the gas streams were combined and passed through a static mixer to ensure proper blending prior to being introduced into the reactor.

The material used as the reaction mass was prepared by blending the following ingredients to homogeneity in a suitable container: 100 parts of silicon, 6.48 parts of cuprous chloride, 600 parts per million (ppm) brass (a 1/1 weight ratio alloy of copper and zinc), 30 ppm tin and 2000 ppm copper

phosphorus alloy containing 13.5 weight percent phosphorus. The resultant mixture of ingredients was mixed shaking vigorously for 2 to 3 minutes. This mixture was then charged to the reactor, following which the reactor was closed and placed in the 315° C. sand bath. At this time a stream of nitrogen was passed through the reactor. The sand bath was continuously fluidized to maintain a constant temperature within the reactor.

When the temperature of the reactor reached about 315° C. the nitrogen was replaced with a stream of gaseous methyl chloride as the fluidizing medium. The flow of methyl chloride was continued for 44 hours. When hydrogen was added it was blended with the methyl chloride throughout the entire methyl chloride addition.

The products emerging from the reactor were condensed and collected in previously weighed cold traps. The liquid collected in the traps was then transferred to cooled bottles and then injected into the sample chamber of a gas chromatograph using a previously cooled syringe. The chromatograph was used to determine the types and concentration of reaction products. The product concentrations reported in the following examples represent the average of two runs performed under identical conditions.

Example 1

This example (Control Example) typifies the product distribution obtained in the absence of hydrogen and hydrogen chloride.

The product distributions from two runs performed without the addition of hydrogen or hydrogen chloride were determined and the results were averaged. The averaged values were:

| | |
|---|-------------|
| Dimethyldichlorosilane (Me_2SiCl_2) | 92.1% |
| Methyldichlorosilane (MeHSiCl_2) | <u>1.3%</u> |
| Total | 93.4% |

| | |
|--|------|
| Dimethylchlorosilane (Me_2HSiCl) | 0.3% |
| Methyltrichlorosilane (MeSiCl_3) | 4.1% |

The remaining material was a mixture of other methylchlorosilanes. There were no detectable amounts of HSiCl_3 or SiCl_4 present.

Example 2

This example (Control Example) demonstrates the high concentration of undesirable methyltrichlorosilane produced together with the increased concentration of methyldichlorosilane when 1.0 weight percent of hydrogen chloride is added to the methyl chloride. The procedure described in Example 1 was repeated, with the exception that 1.0 weight percent of hydrogen chloride was blended with the methyl chloride. The averaged concentration of the reaction products from 2 runs was

| | |
|----------------------------|---------------|
| Me_2SiCl_2 | - 75.0% |
| MeHSiCl_2 | - <u>8.9%</u> |
| Total | - 83.9% |

| | |
|---------------------------|-------------|
| MeSiCl_3 | - 11.8% and |
| Me_2HSiCl | - 0.5% |

Example 3

This example demonstrates the effect of hydrogen in reducing the concentration of methyltrichlorosilane produced by reacting a hydrogen chloride/methyl chloride mixture with silicon. The procedure described in example 1 was repeated, with the exception that 0.5 weight percent hydrogen and 1.0 weight percent of hydrogen chloride were blended with the methyl chloride. The average concentrations of four of the principal methylchlorosilanes in the final product were:

Me_2SiCl_2 - 79.6%
 MeHSiCl_2 - 9.7%
Total - 89.3%

MeSiCl_3 - 4.0% and
 Me_2HSiCl - 1.3%

The presence of hydrogen increased the yield of methyldichlorosilane by 10% relative to Example 2. More importantly, there is almost a three-fold reduction in the amount of methyltrichlorosilane.

Example 4

This example discloses the yields of the major methylchlorosilanes obtained by reacting various proportions of hydrogen chloride, hydrogen and methyl chloride with a silicon-containing reaction mass.

The general procedure described in Example 1 was repeated, with the exception that the weight percentages of hydrogen chloride and hydrogen listed in the following Table 1 were combined with the methyl chloride. These percentages are based on the weight of methyl chloride.

In one instance hydrogen chloride was added only during the first 22 hours of the 44 hour methyl chloride addition.

Table 1

| %HCl | %H ₂ | % Me ₂ SiCl ₂ (A) | % MeHSiCl ₂ (B) | Me ₂ HSiCl(C) | A+B+C | %MeSiCl ₃ |
|------|-----------------|---|----------------------------|--------------------------|-------|----------------------|
| 0.0 | 0.0 | 92.1 | 1.4 | 0.2 | 93.7 | 4.1 |
| 0.5 | 0.5 | 84.4 | 8.1 | 1.3 | 93.8 | 4.0 |
| 0.5 | 0.7 | 85.7 | 7.1 | 1.2 | 94.0 | 3.8 |
| 0.5 | 1.0 | 81.3 | 10.2 | 1.9 | 93.4 | 4.7 |
| 0.7 | 0.2 | 85.0 | 6.9 | 1.0 | 92.9 | 5.1 |
| 1.0 | 0.5 | 79.5 | 9.7 | 1.4 | 90.4 | 6.9 |
| 1.0 | 1.0 | 76.1 | 12.1 | 1.5 | 89.7 | 7.3 |
| 1.5 | 0.5 | 78.4 | 10.7 | 1.0 | 90.1 | 7.0 |
| 1.0* | 0.5 | 80.2 | 10.4 | 2.2 | 92.8 | 4.1 |

* = HCl added during first 22 hours of 44 hours methyl chloride addition

Claims

1. In a method for increasing the yield of methylchlorosilane obtained during the production of methylchlorosilanes by the reaction of a gaseous mixture comprising methyl chloride and hydrogen chloride with a reaction mass comprising silicon metal and a suitable catalyst at a temperature of from 250 to about 350° C., the improvement comprising homogeneously blending the methyl chloride and hydrogen chloride with an amount of gaseous hydrogen sufficient to reduce the concentration of methyltrichlorosilane in the product of said reaction.

2. A method according to claim 1 wherein hydrogen chloride and hydrogen each constitute from 0.01 up to 5 percent of the methyl chloride weight, the reaction between the methyl chloride and silicon is conducted at a temperature of from 260 to about 330° C. in the presence of a catalyst comprising copper or a copper compound and at least one member selected from the group consisting of tin, tin compounds, zinc and zinc compounds.
3. A method according to claim 2 where the combined weight of hydrogen chloride and hydrogen constitute from 0.1 to 3 percent of the methyl chloride weight and hydrogen constitutes from 10 to 60 percent of the combined weight of hydrogen and hydrogen chloride and the reaction mass includes a catalyst/reaction promoter combination selected from the group consisting of copper or a copper compound and zinc or a zinc compound; copper or a copper compound and tin or a tin compound, copper or a copper compound, zinc or a zinc compound and tin or a tin compound; copper or a copper compound, tin or a tin compound and arsenic or an arsenic compound; copper in the form of a mixture, alloy or compound, at least one member selected from the group consisting of tin, tin compounds, zinc and zinc compounds and at least one member selected from the group consisting of phosphorus, phosphorus compounds, metal-phosphorus alloys and metal phosphides; copper or a copper compound, tin or a tin compound, arsenic or an arsenic compound and phosphorus or a phosphorus compound; copper or at least one copper compound and an alloy of silicon with either iron alone or an alloy of silicon, iron and aluminum; 1) copper or at least one copper compound, 2) an alloy of silicon with either iron alone or an alloy of silicon, iron and aluminum and 3) at least one member selected from the group consisting of tin, tin compounds, zinc, zinc compounds, elemental phosphorus, metal phosphides and metal-phosphorus alloys; and a mixture of copper and zinc that is present as brass, cuprous chloride, tin or at least one tin compound and a metal-phosphorus alloy, where the concentrations of any iron and aluminum do not exceed one weight percent, based on the initial weight of silicon.



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EUROPEAN SEARCH REPORT

Application Number

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | EP 90125846.7 |
|---|---|--|---|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
| Y | <u>FR - A - 1 523 912</u> (MOROZOV et al.) * Claims; examples * | 1 | C 07 F 7/16 |
| Y | <u>FR - A - 1 519 715</u> (SHIN-ETSU) * Claims; examples * | 1 | |
| P,X | <u>EP - A2 - 0 348 902</u> (UNION CARBIDE) * Claim 1; example 1 * | 1-3 | |
| | | | TECHNICAL FIELDS SEARCHED (Int. Cl.5) |
| | | | C 07 F |
| The present search report has been drawn up for all claims | | | |
| Place of search VIENNA | | Date of completion of the search 13-03-1991 | Examiner MARCHART |
| CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document | | | |